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Egg dispersal of *Alces tropicalis* in the lower montane rain forest of Monteverde

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Abstract: The tropical moose (*Alces tropicalis*) spends its aquatic juvenile stage in tank bromeliad epiphytes, but the mechanism for their egg transportation to the canopy is unknown. We hypothesized that this transportation is provided by the red-lined poison dart frog (*Phyllobates vittatus*), which transports its own eggs to tank bromeliads in the canopy. We compared the inhabitants of bromeliads in the canopy of Monteverde lower montaine rain forests and predicted that bromeliads with juvenile *A. tropicalis* would also have *P. vittatus* tadpoles. We found a strong relationship between the presence of the two species in the bromeliads. In addition, moose had higher mass in the presence of tadpoles, and more tadpoles were found in bromeliads where moose were also present. These results suggest a mutualistic relationship in which moose recieve transportation and nutritional benefits from the frogs and offer predator defense for the tadpoles. This relationship points to the coevolution of two seemingly incompatible species. The tropical moose and the poison-dart frog have coevolved this seemingly outlandish dependency to take advantage of their respective talents. If all goes well, this finding will provide hope and inspiration to researchers of coevolution around the globe.

Key Words: mutualism, Phyllobates vittatus, *tank bromeliad, Tropical Moose*

Introduction

The Tropical Moose, *Alces tropicalis,* is a rare and elusive species of moose unique to the montane rain forests of Central America. Its life cycle is drastically different from its North American relatives, with an aquatic juvenile stage spent in the water cavities of arboreal bromeliads, followed by a terrestrial adult stage. The transition between these two stages is an awkward time for each moose, as it loses its tail and makes the transition to walking on four legs by spending between 6 and 12 months struggling through the forest on its side, pushing itself with its strengthening legs. It is currently unknown how the eggs of the large ground dwelling adults (up to 150 kg) are transported to the bromeliad cavities high in the canopy (>30m), for its first year of life. Likewise, the mechanism for dispersal from the canopy to the forest floor is also unknown. The two stages were historically considered two separate species until DNA analysis by Bond et al. (1996) revealed them to be two life stages of the same species.

We hypothesized that the transportation of *A. tropicalis* eggs to the canopy epiphytes is correlated with the abundance of the red-lined poison dart frog (*Phyllobates vittatus*), which transports its own eggs to tank bromeliads in the canopy for a juvenile stage similar to that of *A. tropicalis* (Forsyth 1984). We compared the inhabitants of bromeliads in the canopy of Monteverde lower montane rain forests and predicted that bromeliads with juvenile *A. tropicalis* would also have *P.vittatus* tadpoles.

Methods

On 21 - 23 January 2000, we examined the contents of 217 bromeliads between 1500 and 1600 m elevation in the Monteverde lower montane rain forest, Costa Rica. Sampling was done in three randomly chosen 25 m x 25 m plots. Within each plot, we examined all bromeliads visible from the ground. Bromeliads were reached by climbing the host tree. The contents of each cavity were examined and any juvenile frog or moose inhabitants were recorded. The mass and length of each frog or moose was measured. Means were compared by one-way ANOVA.

Results

Of the 217 bromeliads that were examined, 85 contained either *A. tropicalis* or *P. vittatus* inhabitants. Of those, 68 contained both moose and tadpole, 18 contained tadpole only, and four contained only a tropical moose juvenile (Fig. 1). The moose mass was higher when one or more tadpoles were present (Fig. 2; $F_{1,83} = 12.43$, $p = 0.03$). Tadpole mass was not influenced by the presence of moose ($F_{1,83} = 3.21$, $p = 0.19$). Length differences were not significant for either moose or frog ($F_{1,69} = 1.32$, $p = 0.25$; $F_{1,83} = 0.88$, $p = 0.43$, respectively). In the absence of juvenile moose no more than one tadpole was present per bromeliad, while in bromeliads containing moose, we found an average of 4.12 tadpoles (Fig. 3; $t = 5.36$, $df = 7$, $p = 0.007$).

Discussion

Our results suggest a mutualistic relationship between *A. tropicalis* and *P. vittatus*.

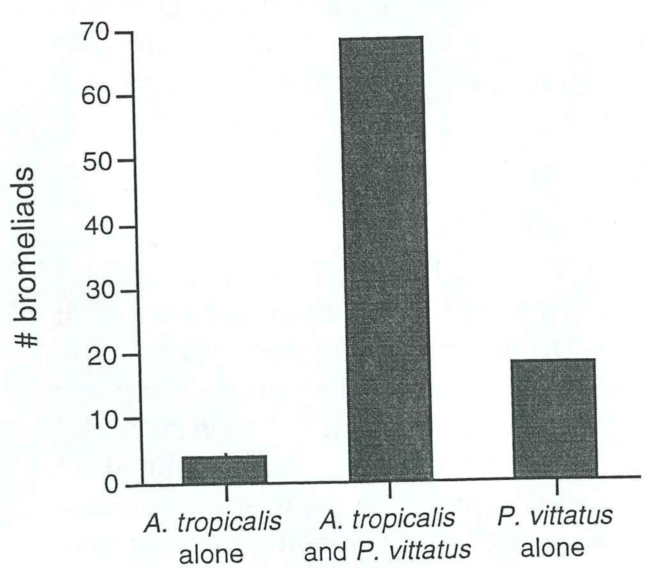

Figure 1. Number of bromeliads found in Monteverde lower montane rain forest, Costa Rica, containing *A. tropicalis* and *P. vittatus* alone and together (n = 217 bromeliads).

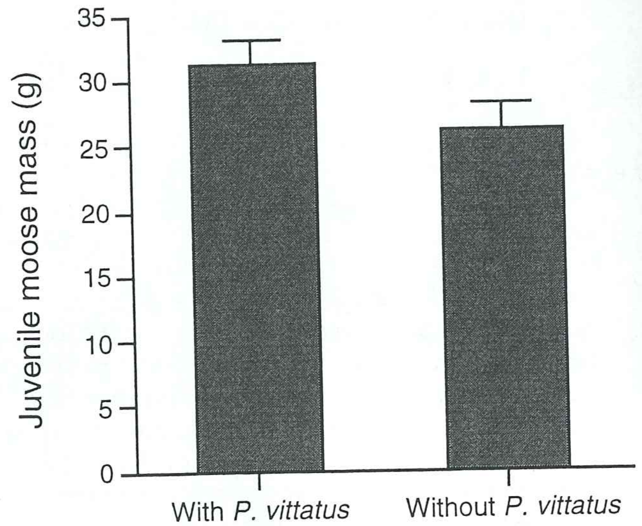

Figure 2. Mass of juvenile *A. tropicalis* individuals with and without the presence of *P. vittatus* tadpoles in bromeliads in Monteverde Cloud Forest, Costa Rica (mean ± SE).

The strong relationship between the presence of juvenile moose and tadpoles suggests that the frog may be responsible for the delivery of moose eggs to the tank bromeliads. In addition, the higher mass of young moose when sharing a bromeliad with a tadpole indicates that the moose achieve higher fitness from the frogs. The female frog periodically climbs to the canopy and lays several unfertilized eggs in the bromeliads with tadpoles, which provide protein for her developing tadpoles (Forsyth 1984). The young moose may also feed on these eggs and thus enjoy a faster growth rate and higher survivorship.

Although tropical moose eggs are roughly three times the size of her own eggs, the female poison dart frog seems to be willing to carry them to the canopy along with her own eggs. Transporting the moose eggs to the canopy is clearly costly to the female frog, implying that the frogs must benefit from the moose larvae. In the absence of moose larvae a greater number of tadpoles were found per bromeliad. Giant damselfly naiads are known to feed on the tadpoles of poison dart frogs (Forsyth 1984). During our study,

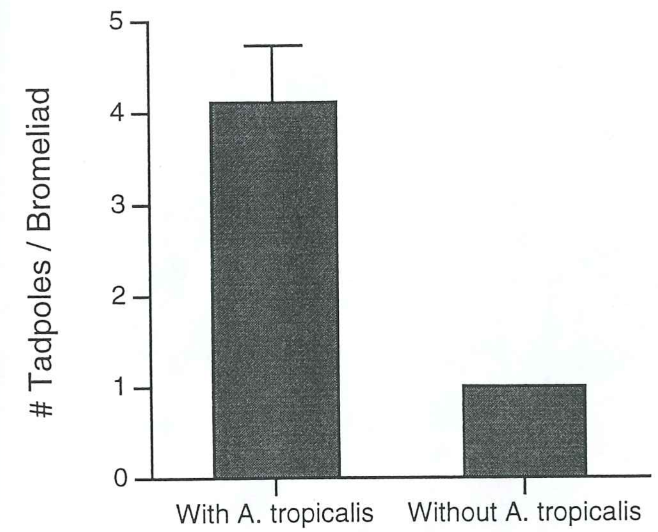

Figure 3. Number of *P. vittatus* tadpoles present in each bromeliad with and without the presence of a *A. tropicalis* juvenile (mean ± SE), in Monteverde Cloud Forest, Costa Rica. In the absense of *A. tropicalis* all tadpoles found in bromeliads were solitary.

we observed three different juvenile moose feeding on damselfly naiads, suggesting that the moose may serve as defense against predation by damselflies. In the absence of moose, a female frog is hesitant to place all her eggs in one plant (basket) because of predation risk. With the defense provided by the moose, the frog can place all her eggs in one plant and reduce energy expenditure by avoiding multiple trips to the canopy.

Although much remains to be learned about the tropical moose, more research investigating its role in predator defense would be valuable. The intricate mutualistic relationship between the tropical moose and the red-lined poison dart frog is of particular interest because it points to the coevolution of two seemingly incompatible species. The discovery of this seemingly outlandish dependency has dramatically expanded the concept of coevolution, which was heretofore limited in its applicability, demonstrating the extent to which the process can mold interspecific relationships.

Literature Cited

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